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Evaluation of Insecticides for Protecting Arizona Cypress (*Cupressus arizonica*) and One-Seed Juniper (*Juniperus monosperma*) from Attack by *Phloeosinus* Bark Beetles

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Abstract. We evaluated the effectiveness of carbaryl, bifenthrin, and permethrin in protecting Arizona cypress (*Cupressus arizonica*) and one-seed juniper (*Juniperus monosperma*) from attack by two bark beetles (*Phloeosinus* spp.). Spray formulations of 2.0% carbaryl (Sevin SL®), 0.03% and 0.06% bifenthrin (Onyx®), and 0.19% permethrin (Permethrin Plus C®) were assessed on bolts (sections of logs) of Arizona cypress for their effectiveness in preventing *Phloeosinus cristatus* attack and colonization. *P. cristatus* broods were produced in all of the Arizona cypress control bolts. Bifenthrin provided ≥80% and ≥70% protection by the 0.06% and 0.03% formulations, respectively, while permethrin and 2.0% carbaryl treatments provided <70% protection. Insecticide sprays (1.0% carbaryl, 0.03% and 0.06% bifenthrin, and

in preventing successful *Phloeosinus* attack. In fact, no studies have been published on preventive treatments for any *Phloeosinus* species. in the southwestern United States. Second, the duration of efficacy for many of these preventive sprays remains untested. In previous studies, Hall et al. (1982) and Hastings et al. (2001) concluded that many of the carbaryl-based products may have residual activity of anywhere from 3 to 27 months. Finally, because there are doubts regarding the reregistration of carbaryl products, new insecticides should be tested (Haverty et al. 1998).

We evaluated several preventive insecticide sprays to address the issues associated with these regional and species differences in insecticide performance (DeGomez et al. 2006). The purpose of this study was to test the efficacy of carbaryl (Sevin SL®, Bayer Environmental Science, Montvale, NJ, U.S.), along with two synthetic pyrethroids, bifenthrin (Onyx®, FMC Corporation, Philadelphia, PA, U.S.) and permethrin (Permethrin Plus C®, Univar, Austin, TX, U.S.) in preventing *Phloeosinus* colonization of cut Arizona cypress.

MATERIALS AND METHODS

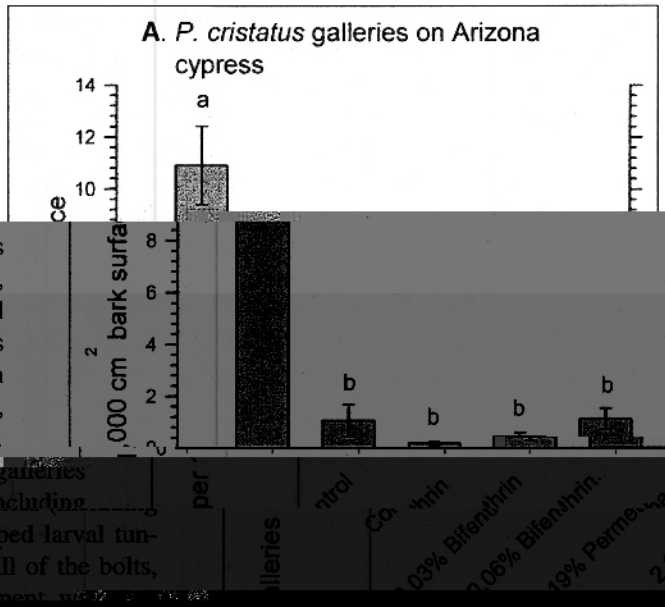
(N34°21.75′, W111°25.72′) between 1645 and 1707 m elevation (5,429 to 5,633 ft) from 14 June to 10 August 2004. The efficacy of four preventive spray formulations was tested: 0.19% permethrin with cellulose additive (Permethrin Plus C®), 0.03% and 0.06% bifenthrin (Onyx®), and 2.0% carbaryl (Sevin SL®). Bolts 1 m (3.3 ft) in length, with 7 to 20 cm (2.8 to 8 in) diameters, were cut from freshly felled pole-sized Arizona cypress trees. Bolts were arranged in a randomized block design; each block consisted of four treatment bolts plus one control bolt placed horizontally on the ground with 0.25 m (0.83 ft) between the bolts and fresh h tree slash surrounding the block. Treatment blocks (24 re licates) were located next to existing roads with 50 m (165 between blocks. To ensure that a sufficient number of be would be present in the vicinity of each block, we select stand containing Arizona cypress with epid *Phloeosinus cristatus*. The insecticide spra the point of runoff to bolts lying on the gro (Scotts Company, New York Mills, NY, U den pesticide sprayer. Each insecti own sprayer to prevent cross-contar

study tested the efficacy of the following four preventive spray formulations: 0.19% permethrin with cellulose additive (Permethrin Plus C®), 0.03% and 0.06% bifenthrin (Onyx®), and 1.0% carbaryl (Sevin SL®). Bolts 1.25 m (4.13 ft) in length and 7 to 20 cm (2.8 to 8 in) in diameter were cut from freshly felled pole-sized juniper trees. Bolts were arranged in the same randomized block design previously described for the Arizona Cypress Experiment. The 24 treatment blocks were located next to existing roads with 50 to 100 m (165 to 330 ft) between blocks. The stand contained evidence of elevated levels of *Phloeosinus* beetles but not high tree mortality. Beetles were identified as *P. scopulorum neomexicanus*.

Insecticides were applied as in the Arizona Cypress Experiment described previously. Bolts were checked for attacks biweekly for ≈15 weeks through 20 July 2004. Attacks by *P. scopulorum neomexicanus* had stopped by this time, most likely as a result of excessive phloem desiccation. All the bolts were brought back to the NAU greenhouse at this point for peeling and evaluation of brood production like in the Arizona Cypress Experiment. When the logs were peeled, we discovered that they did not have completely developed *P. scopulorum neomexicanus* galleries. Instead, the galleries were composed of nuptial chambers, egg galleries (including egg notches), and occasional short, undeveloped larval tunnels. Because this was observed throughout all of the bolts, we assumed that successful larval development was

for the ≥80% protection rate test was also <0.05, we conducted one more test to see if the protection rate was ≥70%.

We also analyzed data on the number of *Phloeosinus* galleries present per 1000 cm^2 (160 in^2) of bark surface area on each bolt. First, we used a Kruskal-Wallis analysis of vari-



ance on ranks to determine if there were differences among the treatments ($\alpha = 0.05$) (Systat Software Inc. 2004). If the overall analysis of variance was significant, we used Dunn's test to conduct pairwise comparisons of all treatment means ($\alpha = 0.05$) (Systat Software Inc. 2004).

RESULTS AND DISCUSSION

Arizona Cypress Experiment

This study exceeded the 60% criterion for test rigor; 100% of the control bolts had *P. cristatus* galleries present (Table 1). None of the insecticide treatments provided ≥90% protection ($P < 0.001$). The 0.06% bifenthrin treatment had a ≥80% protection rate ($P = 0.084$) and the 0.03% bifenthrin provided ≥70% protection ($P = 0.071$). The 0.19% permethrin and the 2.0% carbaryl treatments had protection rates <70% ($P \leq 0.009$). All the treatments had lower densities of *P. cristatus* galleries compared with the control, but none of the spray treatments differed significantly from each other (Figure 1A). One of the control bolts was most likely removed from the study site by vandals.

One-Seed Juniper Experiment

In this experiment, 62.5% of the control bolts had *P. scopulorum neomexicanus* galleries, thus meeting our 60% criterion for [illegible] (Table 2). The 0.03% and 0.06% bifenthrin and the 0.19% permethrin sprays all provided ≥90% protection ($P \geq 0.691$), and they had gallery densities lower than the control (Figure 1B). The 1.0% carbaryl treatment had ≥80% protection ($P = 0.161$), but the gallery density for this treatment did not differ from the control or any of the other treatments (Figure 1B). Identification tags from two of the bolts of the 0.03% bifenthrin, 0.06% bifenthrin, and the 0.19% permethrin and one bolt of the 2.0% carbaryl were lost during the transport of the bolts from the field to Northern Arizona University greenhouse complex.

The 0.06 and 0.03% bifenthrin, 0.19% permethrin, and 2.0% carbaryl (2.0% carbaryl only tested against *P. cristatus*) all performed well in terms of bark beetle attack pressure; gallery densities were reduced 10-fold compared with the controls. It is our opinion that under a natural setting (non-baited live trees), these insecticide treatments would provide sufficient protection.

The 2.0% carbaryl formulation tested in the Arizona Cypress Experiment had mixed results. Although it provided <70% protection of the bolts (Table 1), it reduced gallery density significantly compared with the control (Figure 1A). The inadequate protection could have been caused by poor bark coverage or penetration by the formulation we used; the bark on the younger wood of Arizona cypress tree boles is smooth and waxy, which may have caused coverage problems. Protection rates might be improved by adding spreaders and stickers to this formulation.

The 1.0% carbaryl treatment in the one-seed junip[illegible] periment provided ≥80% protection (Table 2), but it significantly reduce overall gallery density (Figu[illegible] These results prevent us from recommending 1.0% sprays for prevention of *Phloeosinus* spp. attacks.

Questions still remain regarding the duration of sidual activity of these treatments. Two percent carba[illegible] mulations have been shown to be effective for one beetle flight seasons in western bark beetle species 1977; Shea et al. 1984; Haverty et al. 1985; Werne 1986). Environmental factors that affect the breako[illegible] pesticide treatments o[illegible] temperature, can vary DeGomez et al. (200[illegible] 0.06% and 0.12% bif[illegible] SL®), and 0.19% perm[illegible] additive) sprays appli[illegible] Dougl ex. Laws.) bolt[illegible] against pine engraver[illegible] ment. A conservative[illegible] the bifenthrin and pe[illegible] *Phloeosinus* beetle fli[illegible] before beetle flight i[illegible] extend for another yea[illegible] protection that might b[illegible]

These results may have economic consequences when selecting which insecticide to use given that the base cost of using these insecticides is highly variable. We estimate that ≈13 L (3.4 gal) of mixed insecticide would be used on individual cypress or one-seeded juniper trees. The cost of the insecticide to spray a tree would vary from $7.00 (U.S.) for the 2.0% carbaryl to $5.40 for the 0.06% bifenthrin and $1.80 for the 0.19% permethrin (with cellulose additive). The permethrin was one-fourth the cost of the 2.0% carbaryl and one-third the cost of the 0.06% bifenthrin. We assume that other permethrin products without the cellulose additive, labeled for bark beetle control, would have similar efficacy to the Permethrin Plus C® that we tested for practically the same cost per tree. We caution against using insecticides that are not specifically labeled and formulated for protection against bark beetles because they will be ineffective and economi-

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the University of Arizona or the U.S. Department of Agriculture Forest Service.

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étaient présentes sur 62,5% des sections témoins de tronc de genévrier à une graine. De[illegible] sur la présence de galerie versus l'absence de *P. scopulorum neomexicanus* ont indiqué que traitements avec du bifenthrin à 0,03% et à 0.06% ainsi que permethrin à 0,19% donnaient plus de 90% de protection, et c[illegible] que le carbaryl à 0,6% donnait plus de 80% de pr[illegible] pour prévenir la colonisation. La formulation de bi[illegible] est celle qui donne la meilleure protection contre les *Phloeosinus*.

Zusammenfassung. Wir bewerteten die Effekt[illegible] ryl, Bifenthrin und Permethrin im Einsatz gegen B[illegible] bei Cupressus americana und Juniperus monosperm[illegible] wahl von Zypressenstämmen wurde[illegible]